PROGRAMMING FOR REINFORCED CONCRETE DESIGN FOR TWO-WAY RESTRAINED SOLID SLAB TO EUROCODE 2

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
B.Eng (Hons.) Civil Engineering

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JUNE 2015

ABSTRACT

In this research, a program is coded by using Microsoft Small Basic in order to carry out the calculations in reinforced concrete design for two-way restrained solid slab as according to Eurocode 2 standards. The aim and objectives of this research is to provide a faster and accurate way to solve reinforced concrete design tests and questions. Other than that, this also seek to provide a free alternative to students or lecturers with minimum system requirements that would work on any Windows operating system as compared to the more advanced yet expensive available software on the market. Coding of the program is done using Microsoft Small Basic, utilizing a simple BASIC programming language, one of the easiest programming to learn and use. Microsoft Small Basic does not require high-end computer specifications including the programs coded through it. Coding is giving instructions to a computer in a language it can understand with the correct syntax. The Program would require certain values to be inputted by the user before proceeding with calculations. Once the program is finished in its coding, its accuracy is then compared to manual calculations of provided questions. This research would act as an aid to users to carry out reinforced concrete design via a free and easy to use software for quick and precise answers.

ABSTRAK

Dalam kandungan penyelidikan ini, satu perisian berkod dibina melalui penggunaan *Microsoft Small Basic* untuk mejalankan reka bentuk konkrit bertulang untuk papak dihalang dua hala atas standard *Eurocode 2*. Matlamat dan ojektifs penyelidikan ini adalah untuk menyediakan satu cara yang pantas dan tepat untuk pengiraan reka bentuk konkrit bertulang dalam ujian dan soalan. Selain daripada itu, penyelidikan ini juga bertujuan untuk membuat perisian tersebut percuma untuk digunakan oleh para pelajar atau cikgu tanpa mengunakan spesifikasi computer yang melampau berbanding dengan perisian-perisian yang ada dalam pasaran. Pengekodan perisian tersebut menggunakan *Microsoft Small Basic* dan bahasa komputer *BASIC* yang disenangkan. Bahas computer tersebut adalah antara paling senang untuk dipelajari dan digunakan. Pengekodan adalah cara untuk berkomunikasi dengan komputer dalam bahasa yang komputer boleh memahami dengan sintaks yang betul. Perisian tersebut akan memerlukan pengguna untul menginputkan data sebelum pengiraan bermula. Setelah pengekodan perisian tersebut tamat, ketepatan perisian tersebut dibandingkan dengan pengiraan manual. Kajian ini akan bertindak sebagai bantuan kepada pengguna untuk menjalankan kerja mereka bentuk konkrit bertetulang melalui perisian percuma dan mudah untuk digunakan untuk mendapatkan jawapan yang cepat dan tepat.

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LIST OF SYMBOLS

%	Percent
mm	Millimeter
m^2	Square meter
mm^2/m	Square millimeter per unit meter
MPa	Mega Pascal
kN/mm^2	Kilo newton per square millimeter
kN	Kilo newton
n	Total ultimate load per unit area
n_{ed}	Design action
°C	Degree Celsius
G_k	Characteristic Permanent Action
Q_k	Characteristic Variable Action
L_y	Length of longer span
L_x	Length of shorter span
M_{sx}	Maximum moment per unit width
b	Width of slab
d	Breadth of slab
z	Lever arm
h	Slab Thickness
d_x	Effective depth
d_y	Effective depth
β_{sx}	Moment coefficient for short span
β_{sy}	Moment coefficient for long span
β_{vx}	Shear coefficient for short span
β_{sy}	Shear coefficient for long span
C_{nom}	Nominal Cover
ϕ_{bar}	Diameter of reinforcement bar
$A_{s,min}$	Minimum area of reinforcement
$A_{x,max}$	Maximum area of reinforcement
$A_{s,req}$	Required area of reinforcement
$A_{s,prov}$	Provided area of reinforcement

A_{sl}	Area of tensile reinforcement that extends $\geq (l_{bd} + d)$ beyond the section considered
b_w	Smallest width of the section in tensile area
f_{ctm}	Mean values of the axial tensile strength of concrete
f_{ck}	Characteristic strength of concrete
f_{yk}	Characteristic strength of steel
V_{sx}	Design shear force
V_{ed}	Maximum shear force
$V_{rd,c}$	Design shear resistance without shear reinforcement
V_{min}	Minimum shear force
$S_{max,slabs}$	Maximum bar spacing for slabs

LIST OF ABBREVIATIONS

UMP	University Malaysia Pahang
ACI	American Concrete Institute
BS	British Standards
MS	Malaysian Standards
EN	European Standards
RC	Reinforced Concrete
EC	Eurocode 2

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

From rapid development of buildings to astounding technological discoveries, the modern world is ever on the rise in progress. Countless technological wonders are explored and adapted to our everyday lives and much of these technology help in solving complicated situations. Much of these complicated situations come from basic calculations which in turn are derived and transformed into something much bigger and complex to solve even bigger problems. Software and Programs are utilized by computers to execute the most complicated tasks of lengthy calculations with precision and in a short amount of time giving more options to new projects in which calculating manually would use up too much time and waste resources. All of these software and programs would not have been made possible without the basics of programming and coding of said software.

Computer Programming is essentially a process that comes from an original formulation for computing problems that turns into an executable program in which it will carry out the written formula. For example you can program and code a simple calculator to carry out simple calculations. There are much software that assists in the creation of new software such as Microsoft Small Basic, Visual Basic and Java. These softwares utilize a programming language as a way of communicating with machines via given instructions. There are various programming languages available but the most used is Java which is abundantly used throughout the world in various platforms.

Since it is capable of quick calculations, the field of civil engineering is no stranger to sophisticated software in their line of work. Likewise for reinforced concrete designs which have many calculations to be calculated, benefits greatly from quick and precise calculations that specialized software can offer.

1.2 PROBLEM STATEMENT

Carrying out manual calculations is very tedious and may take a long time to finish for us to get the answers that we want. With the current rapid development of our country today, having a system for carrying out the said calculations in a short amount of time is a

There are plenty of sophisticated software and programs designed for civil engineering purposes such as AutoCAD, Esteem and Orion available in the market. However, not many of such software are easily available to students for study purposes. Some require older Operating Systems that are outdated and have errors plus complications if they were to be run on newer generation of Operating Systems. Even universities and colleges may not be able to provide the latest versions of said software as they are very costly.

In order to provide an easier and cost-free way for students or anyone who has interest in reinforced concrete design, this research is to study programming and coding from which will in turn produce a simple interactive software that would carry out the calculations in reinforced concrete design and still adhere to given rules from Eurocode 2.The main structural element type in question would be two-way restrained slabs and its analysis of bending moment and shear force

1.3 AIM AND OBJECTIVES

The main aim of this research is to successfully program and code using Microsoft Small Basic in order to calculate and analyze two-way restrained slabs for reinforced concrete design for all 9 cases of slab position

- To provide an easy interface for users to use and input values to the program which will carry out the calculations in a short amount of time
- To successfully allow the program to carry out calculations for the analysis of reinforced concrete design for two-way restrained slabs

1.4 SCOPE OF RESEARCH

The following is a list of the scope covered by this research:

1. The programming and coding will utilize and only coded through Microsoft Small Basic
2. Only Two-Way Restrained Solid Slabs are to be used and includes all 9 cases of the slab position
3. To the test the accuracy of the program, values of the slab's properties are provided and manually calculated to be used to compare the results gained from that of the program's outputs to the example's answers.
4. Calculations and rules are based on Eurocode 2 of Two Way Restrained Solid Slab for Reinforced Concrete Design. Calculations will begin at Design Action to Bending Moment Analysis for Main Reinforcement to Shear Force Analysis and finally Crack Checking in which will be calculated by the program but not shown on the screen.
5. Deflection Checking and Detailing is not included in the scope
6. Bending Moment Coefficients and Shear Force Coefficients will solely be based on Table 3.14 and Table 3.15 of BS8110:Part1:1997. These tables are Table 3.1 and Table 3.2 in this research report. It will not consider any values between and outside of the ratio of L_y/L_x given in the tables nor are the values of the coefficients themselves.
7. The values to be inputted once the program is finished are to follow the given units:
   a) Permanent Characteristic Action (unfactored and includes self-weight of slab), G_k: kN/m^2
   b) Variable Characteristic Action(unfactored), Q_k in kN/m^2
   c) Characteristic Strength of concrete, f_{ck}: N/mm^2
   d) Characteristic Strength of steel reinforcement, f_{yk}: N/mm^2

e) Long Span and Short Span of slab; L_y and L_x in mm
f) Slab Thickness, h in mm
g) Nominal cover, C_{nom} in mm
h) Case
i) Diameter of reinforcement bar, ϕ_{bar}: mm
j) Area of linkage(corresponding to the $A_{s,prov}$ at the support whichever is highest), A_{sl} in mm^2/m
k) Mean tensile strength of concrete, f_{ctm} in MPa

1.5 RESEARCH SIGNIFICANCE

This research is for the purpose of saving time and shortening the lengthy processes in the analysis of two way restrained slabs for reinforced concrete design. With the program finished in its coding, it would be able to calculate and analyze the slab within mere seconds after the values are inputted correctly with accuracy and speed. The finished program would provide accurate results and can be run on any Windows Operating System requiring minimal computer specifications and without draining much of the computer's resources. In addition, the program can be easily use with an easy interface to interact with the users by simple inputting values into given boxes and pressing buttons on the interface to proceed, reset or exit the program. The program would also be considered free to use for academic purposes and would not require any sort of payment for its usage.

1.6 EXPECTED OUTCOME

Once the program is finished in its programming and coding, the program will:

1. Able to be executed with any computer that has Microsoft Small Basic installed and its requirements
2. Read inputs given such as Characteristic Actions, Characteristic Strength of concrete and steel, length and width of slab, nominal cover, slab thickness, and Slab Position Case.
3. Once inputs are correctly added, clicking "Calculate" button will begin the calculation process and analyze the Two-Way Restrained Slab.

4. Calculations will not be shown on-screen but it will give the answers on the screen for the following:

   a) Area of the slab, A in mm^2
   b) Design action, n in kN/m^2
   c) Ratio of L_y/L_x
   d) Case
   e) Bending moment coefficients for short span β_{sx} and β_{sy}
   f) Bending moments: M_{sx1}, M_{sx2}, M_{sy1} and M_{sy2} in kN/mm^2
   g) Diameter of bar in mm
   h) F_{ctm} in kN/mm^2
   i) Effective depths, d_x and d_y in mm
   j) Minimum and maximum reinforcement area in mm^2
   k) Areas of reinforcements for long spans and short spans with their respective mid spans and support, As in mm^2/m
   l) Values of k and z for the calculation of area of reinforcement
   m) Design shear forces: V_{sx1},V_{sx2},V_{sy1} andV_{sy2}
   n) Maximum shear force, V_{ed}
   o) Design Shear Resistance, $V_{rd,c}$
   p) Minimum Shear Force, V_{min}
   q) Maximum Bar Spacing for Main and Secondary Bars

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will cover up the literature review done throughout this research on topics relevant to the research. Two major topics are discussed which are Reinforced Concrete and Software Programming. Reinforced Concrete covers short summaries of reinforced concrete, slabs, reinforced concrete and design standards whereas Software Programming covers up topics on Software and Programs, Software available for Civil Engineering, Software available for Reinforced Concrete Design, Software Architecture and Programming Languages.

2.2 REINFORCED CONCRETE

Concrete is a major construction material that has been used for millennia by countless civilizations with the oldest dated concrete in the regions of southern Syria and Northern Jordan around 6500 BC (Gromicko & Shephard, 2015). It is a stone like substance produced when prepared carefully through the combination of cement, sand, gravel and water. The shape and size of the finished concrete can be set during the mixture of the elements by putting the mixture into a mold of desired dimensions (Jamal, 2014). Its advantages lie in its high compressive strength which requires low maintenance and would last a very long time in comparison to timber and steel. However, its weakness lies in its low tensile strength. It may easily crack when enough stress is applied to it. Therefore, concrete are usually reinforced with various other materials that have high tensile strength and the most abundantly used is reinforcement steel bars. This is called Reinforced Concrete.

Reinforced Concrete utilizes the concrete's high compression strength with a material that has high tensile strength and ductility of steel. Often called 'rebar', reinforcement steel bars are widely used in the production of reinforced concrete for buildings. Steel reinforcement bars are usually round as round surface areas provide the most possible surface area to the surrounding concrete thus providing a better bond between the molecules with concrete (Gambhir, 2008). The concrete mixture would surround and interlock with the steel bars and upon hardening of the concrete, reinforced concrete is produced (Jamal, 2014).

The compressive strength of reinforced concrete is dependent on the hardened concrete whereas the tensile strength is dependent on the reinforcement steel bars (Gambhir, 2008).

The strength of hardened concrete is dependent on these following factors (Sinha, 2002):

1) Fineness and type of cement used

   Certain types of cements have the ability for rapid hardening and have low heat such as Portland cement. The fineness of the cement influences rate of strength gain of concrete

2) Strength, shape, size, grading and surface texture of aggregate

   The aggregate's physical properties influence the strength of concrete via molecular bonds. The grading of aggregate does not directly influence the strength of concrete but rather its workability.

3) Water to cement ratio

   Coarse aggregate produces higher workability. Water/Cement ratio affects the strength of concrete via the equation A.

4) Aggregate to cement ratio

   An increase in aggregate to cement ratio increases compressive strength of concrete given water to cement ratio is constant.

5) Temperature and Curing Time

The temperature during curing of concrete affects water loss via evaporation. During the hardening of the concrete, the concrete is required to be saturated to prevent loss of water and strength loss. Temperatures above 23 °C would increases initial strength gain but decreases after 2-3 days. Temperatures below 23 °C would have a continuous strength gain at a rate that decreases overtime.

6) Concrete Age

The strength of concrete increases with age of the concrete where it would the concrete would harden rapidly with its strength increasing rapidly and reaching up to 66% of the final strength in 7 days. The rate of strength gain decreases slowly after that and it would reach up to 90% at 28 days. The rate becomes very low and it would increase very slowly as compared to the first few days.

Reinforced concrete provides plenty of advantages to the users such as high compressive strength, high tensile strength, good fire and weather resistance, flexibility in molding them into countless shapes and sizes and low maintenance cost (Civil Today, 2014). However, it is not without its disadvantages such as the requirement of mixing, casting and curing; all of which would affect the concrete strength, the high cost of the forms to mold the concrete and the its tensile strength is one-tenth of its compressive strength (Jamal, 2014).

2.2.1 Slab

Slabs is one of the most widely used structural element as it forms the floors and roofs in order to support loads normal to the surface floor. The slabs maybe supported on tops of walls or on columns or even the beams (Sinha, 2002). It carries gravity loads normal to the slab's surface and then transfers the loads to the supports via flexure. The slabs can be simply supported or even continuously span over more than one supports (Yassin & Abdullah, 2012). Slabs that have their flexural loads transferred from the slab to the supports can be split into two categories; One-way Slab or Two-way Slab. They are dependent on the ratio of the longer span to the shorter span of the slab. One-way slab requires the ratio to be greater than 2 whereas Two-way slab requires the ratio to between 1 and 2 (Gambhir, 2008).

One way slabs is assumed when the predominant flexural mode is only in one direction. Rectangular slabs that are supported only on two sides opposite of each other by walls or beams where the loads are uniformly distributed along the direction that is parallel to the supports (Devadas, 2003)

When the ratio between the longer span and the shorter span increases, the curvatures and moments along the long span would gradually reduce. The slab loads would effectively increase in its transfer to the longer span's supports by bending in the short span's direction (Devadas, 2003). However, if the slab is square and is restrained similarly on all four sides, the load is distributed equally in both directions (Yassin & Abdullah, 2012).

There are two types of two-way solid slabs which are simply supported slab and restrained slab. Simply supported slabs have its all four sides deflect about both axes under loads where its corners would lift and curl up from the support. This event causes torsional moments. Restrained slabs are dependent on the slabs edges whether they are continuous edges or fixed. There are a total of nine different support cases for two way slabs and can be found in Figure 3.4.1. Torsion reinforcement is required at discontinuous corners and needs to consist of both top and bottom mats with each having the reinforcement bars span in both directions. This reinforcement should extend from the edges at a minimum distance of $L_x/5$ whereas the area in each four layers should be 75% of the area required of maximum mid-span moment. Torsional reinforcement is not needed when the edge is continuous in both directions (Yassin & Abdullah, 2012).

2.2.2 Other Types of Slab

There are four other types of slabs which are Ribbed slabs, Waffle slabs, Flat slabs and Flat slabs with drop panel (Yassin & Abdullah, 2012). Ribbed slabs are slabs that are integrated with a series of closely spaced joists during casting. These joists are then supported on a set of beams. The design of ribbed slabs is that it is a series of parallel T-beams which proves to be economical for medium spans that have very small to medium live loads.

Waffle slabs are much like two-way slabs but it is reinforced by ribs in both directions. It is capable of carrying relatively heavier loads and can be of longer span compared to ribbed slabs.

Flat slabs are slabs of uniform thickness, reinforced in both directions and is supported directly by columns without beams.

Flat slabs with drop panel are normal flat slabs with the addition that its column supports improved with drop panels. This would increase its shear strength and is capable of resisting stronger moments.

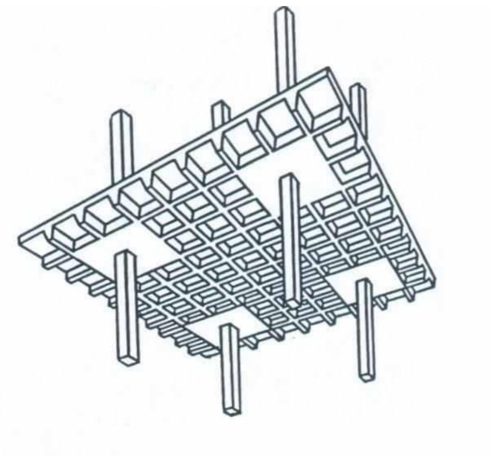

Figure 2.2.1 Waffle Slab

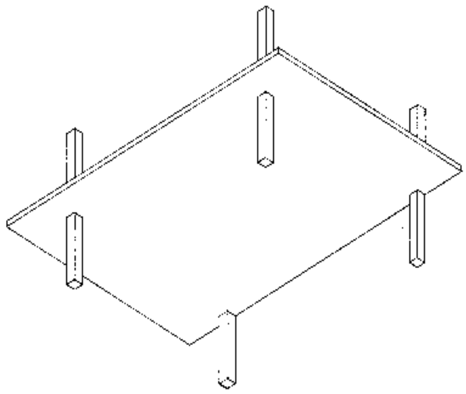

Figure 2.2.2 Flat Slab

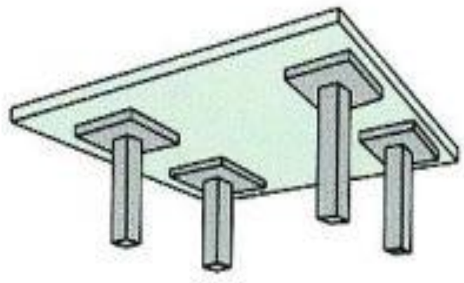

Figure 2.2.3 Flat Slab with Panels

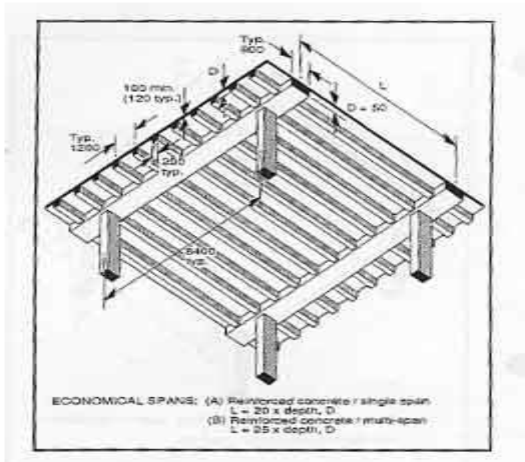

Figure 2.2.4 Ribbed Slab

2.2.3 Reinforced Concrete Design

The design of a structure can be regarded as the process of choosing materials and elements proper for the structure. Depending on the requirements of the structure, design methods can be split into two categories which are: Ultimate Limit State and Serviceability Limit State. Ultimate Limit State covers the strength and stability of the structure under maximum design load in which the structure is expected to withstand. This also means that no part of the structure should encounter failure such as cracking, collapsing or buckling. Serviceability Limit State covers conditions in which specified service requirements are no longer met (Yassin & Abdullah, 2012). Theoretically, the bending for reinforced is based on the assumptions from EN 1992:Cl 6.1 (2)P. which are:

1) The plane sections before bending must remain after the bending.
   This implies that the normal strains are distributed across the section is linear

2) The strain in bonded reinforcement, either tension or compression is the same throughout the surrounding concrete
   This assumption is necessary due to the fact that the concrete and reinforcement act together to carry loads

3) Concrete tensile strength is ignored

Concrete tensile strength is roughly one tenth of the its compressive strength which is regarded as too small and can be neglected.

4) Stresses in the concrete and reinforcement is derivable from the strain by using the stress-strain curves for concrete and steel

Ultimately, reinforced concrete design to EC 2 has these following procedures; flexural design, shear design, deflection checking, cracking checking and detailing. Flexural design is based on bending moments acting on the structural element. It is the design of the specifications of the reinforcement steel bars such as diameter size and spacing to be used with concrete with regards to the loads. The plastic behavior of reinforced concrete at ultimate limit state affects how the moments are distributed in a structure. Plastic hinges that forms in the reinforced concrete requires large rotations with yielding of the tension reinforcement. Shear design is the design of reinforcement steel bars to link each other in order to resist shear forces. Shear forces is transmitted through crack member via a combination of other un-cracked concrete in zone of compression, dowelling action of the flexural reinforcement and aggregates that interlock across the cracks of tension. Deflection checking requires that the span of the structural element is not high enough to lead to excessive deflection such as sagging of floors, partitions being crushed, buckling and so on. Cracking checking is to limit the width of individual cracks for durability and corrosion protection (Yassin & Abdullah, 2012).

2.2.4 Codes of Practices

Codes of practices and design standards such as ACI, Eurocode and British Standards are sets of technical specifications that act as a control of important details of design and construction (Jamal, 2014). These codes of practices have the sole purpose to produce sound and safe structures in order to protect the public from inadequately designed structures and constructions. Below is some of the design standards used all over the world:

a) American Concrete Institute

The American Concrete Institute or ACI was founded in 1904 and acts as the leading authority and resource worldwide in the development and distribution of many design standards. Their main mission has always been the same which is to provide knowledge and information for the best use of concrete. ACI 318 Building Code Requirements for Structural Concrete is one of the most used design standards in America which is to provide minimum requirements for the design and construction of structural concrete under the requirements of a common code of building that is incorporated with it (ACI, 2015).

b) Eurocodes

Eurocodes are a set of technical rules that are consensus-agreed developed by the European Committee of Standardizations for the structural design of works regarding construction mainly used in the European Union. The standards are published separately where each member has a number of parts. By March 2010, the Eurocodes were considered mandatory for European public works.

2.3 SOFTWARE AND PROGRAM

A software comprises the electronic instructions that govern the computer’s functions (Kenneth & Baldauf, 2008). A program consists of sequences of instructions to a computer, where it is written to perform specified task on a computer (Ralph, 2003). Unlike a program where a program is developed by individuals for their own personal use, software is much more complex. It is meant for multiple users and therefore has a good interface, designed systematically, thoroughly tested and implemented carefully. Software is most often very complex and too large for one person to create and develop singlehandedly (Rajib, 2004). For example, given a software that records names and addresses in a database. The program and database is considered a part of the software but the database is not a program (Ben, 2010).